TEST PROCEDURE	TP 310A
Title	**Page Number**
Critical Flow Orifice Verification	1 of 18
Originator	**Supersedes**
David Munday, Mechnaical Engineer, Calibration and Maintenance	TP 310
Responsible Organization	**Computer Program**
Calibration and Maintenance (C&M)	CFO Verification Program
Type of Test Report	**Data Form Number**
Computer	Form 310-01
Report Distribution	**Implementation Date**
Calibration and Maintenance	09-30-94

Implementation Approval

Original Test Procedure Authorized by EPCN #102 on 02-03-92

Revision Description

This procedure has been edited as described in EPCN #147. Page layout, grammatical, and spelling changes have been made, but there were no technical revisions to the procedure.

Note: Specific brand names in EPA/EOD procedures are for reference only and are not an endorsement of those products.

Table of Contents

Attachments

1. **Purpose**

   The purpose of this procedure is to verify the calibration of the Critical Flow Orifices (CFOs).

2. **Test Article Description**

   Critical flow orifices are used for propane tracer gas injections.

3. **References**

   3.1   "Instruction Manual for the Critical Flow Orifice Kit, Model 210," Horiba Instruments Inc., November 1978

   3.2   Letter from Horiba Instruments, Inc., to MSAPC QA Staff, August 1979

   3.3   "Brooks Vol-U-Meter Operating Instructions," Models 1052 through 1058, Brooks Instrument Division, Emerson Electric Company, 407 West Vine Street, Hatfield, PA 19440; December 1977, Revision A

   3.4   "Code of Federal Regulations," Title 40, Part 86, Section 86.119

   3.5   Memo: David L. Munday, November 5, 1991, Subject: "Equations for CFO Calibration"

Required Equipment

   The following is a list of the equipment used to perform a CFO verification:

   4.1   Instrument grade propane

   4.2   Conoflow single stage regulator; 0-125 lb spring, non-relief type

   4.3   Shutoff valve

4.4   The following components, see Attachment A, are contained in the CFO kit:

    4.4.1   Precision pressure gauge; 0-100 psig, 8-inch diameter scale or larger, graduated in 0.2 psig increments

    4.4.2   Thermometer, 0-120 °F, graduated in 0.5 °F increments

4.5   The following components are contained in the Brooks Vol-U-Meter System, see Attachment B:

    4.5.1   Brooks Vol-U-Meter Control Box

    4.5.2   Valves; 3-way solenoid activated; two required

    4.5.3   Connection tubing and large, non-restricting vent and dump lines

    4.5.4   Back-pressure manometer; 0-4 inches of water, graduated in 0.5-inch increments

    4.5.5   Brooks Vol-U-Meter, Model 1057; 3500-cc capacity (this is known as the Brooks Prover)

4.6   Seeka F5 optical sensors; two required

Note: One sensor is mounted at the 500-cc mark and the other is mounted at the 2000-cc mark, see Attachment B, Figure 2.

4.7   DCI Timer with toggle switch

4.8   Mensor Digital Pressure Gauge (central barometer), Model 11900; 0-32 inches of Hg, graduated in 0.001-inch increments.

4.9   Vertex Floor Scale, Model 2158; equipped with Toledo Indicators, Model 8146

Note: The scale is located in the large soak area.

4.10   CFO Kit/Cart Information, see Attachment C

4.11   Form 310-01, "CFO Verification Data," see Attachment D

4.12   "CFO Verification Report," see Attachment E

5.   **Precautions**

5.1   Cylinders containing compressed gases are used for this procedure. The technician must be familiar with the "Environmental Protection Agency (EPA) Laboratory Safety Manual" sections dealing with the safe handling, storage, and use of compressed gas cylinders.

5.2   The gas cylinders and equipment must be checked for leakage, damage, and cleanliness.

5.3   Use the Brooks Vol-U-Meter only with approved gases (see the operating manual for details).

5.4   Although CFO kits have orifices for use with CO, pure CO should not be used because of its extremely toxic properties. For safety reasons, EPA does not permit CO injections as a routine practice.

5.5   The CFO kit must be in the gas lab prior to the start of the verification for a minimum of 20 minutes to ensure the kit is at room temperature.

5.6   After each adjustment is made to the targeted pressure, the flow rate is allowed to stabilize for a minimum of two minutes.

5.7   The precision pressure gauge is graduated in 0.2-psig increments but must be read to the nearest 0.1 psig.

6.   **Visual Inspection**

6.1   Inspect all fittings with a leak detection fluid when the system is pressurized to 85 psig (see Section 7 for details).

6.2   Verify that the CFO kit precision pressure gauge reading is zero when the shutoff valve is closed.

6.3   Verify that the Brooks Vol-U-Meter back-pressure manometer reading is zero on the left side of the u-tube when the Control Box is in the "off" position.

If it is not zero, release the set screws in the sliding metal scale and adjust it so the zero mark lines up with the bottom of the meniscus (on the left side).

7.   Test Article Preparation

7.1   Disconnect the rosette from the cylinder pressure line.

7.2   Using the Vertex floor scale, weigh the CFO kit/cart (CFO kit, propane cylinder, and cart).

Record the CFO total weight on Form 310-01. The CFO Verification Program calculates the net weight of the propane in the tank by subtracting the tare weight (displayed on each kit/cart combination) from the total CFO kit/cart weight.

See Attachment C, for details.

For a valid verification, the net weight of the propane in the tank must be greater than 25 lbs. If it is not, replace the propane cylinder.

7.3   Ensure that the DCI timer and the Brooks Vol-U-Meter Control Box are plugged into an electrical outlet.

If not, plug them in and allow the equipment to warm up for a minimum of two hours.

7.4   Push the Brooks Vol-U-Meter Control Box button to the "off" position.

7.5   Connect the cylinder pressure line to the Brooks Vol-U-Meter Control Box inlet pressure fitting.

7.6   Adjust the regulator to 85 psig and allow the pressure to stabilize for a minimum of two minutes.

7.7   Push the Brooks Vol-U-Meter Control Box button to the "flow" position.

7.8   Verify that there are no fluctuations in the piston movement and back-pressure manometer reading. If fluctuations exist, notify the C&M Manager.

7.9   When the piston reaches the top optical sensor, turn the cylinder valve counterclockwise to the "closed" position. The system will now be pressurized.

7.10   Inspect all fittings with a leak detection fluid.

7.11   Push the Brooks Vol-U-Meter Control Box button to the "off" position.

7.12   On Form 310-01, Section A, record all the required data. The previous calibration date and active coefficients are stored in the CFO folder. The CFO folder is stored in the Gas Lab. The cylinder number, purity, and vendor are located on the tank.

8.   Test Procedure

A total of 8 data points are collected for a CFO verification. Each data point consists of a measured supply pressure, within 60 to 95 psig range, and an elapsed time reading. The target pressures are 60, 75, 85, 70, 90, 95, 80, and 65 psig.

For each of the target pressures, perform the following steps:

101   Turn the cylinder valve clockwise to the "open" position.

102   Push the Brooks Vol-U-Meter Control Box button to the "off" position.

103   Adjust the regulator to set the supply pressure to within ±0.4 psi of the target pressure, e.g., 60 psig must be 59.6 - 60.4 psig, 75 psig must be 74.6 - 75.4 psig, etc., for all target data points.

104   Allow the set pressure to stabilize for a minimum of two minutes. The stabilized pressure must be within ±0.4 psig of the target pressure.

105   Read the precision pressure gauge to the nearest 0.1 psig.

106   On Form 310-01, Section B, record the observed pressure under the column Actual psig.

107   When the Brooks Vol-U-Meter piston has descended to the bottom of the chamber, push the DCI toggle switch to the right to stop the timer. Reset the timer to zero by pushing the toggle switch to the left.

Note: If this is the start of the verification process, the piston will already be at the bottom of the chamber.

108   Push the Brooks Vol-U-Meter Control Box button marked "flow." This directs the flow into the Brooks Vol-U-Meter, causing the piston to rise.

109   Verify that the Brooks Vol-U-Meter back-pressure manometer reading is 1.5 inches of water. If it is not, notify the C&M Manager.

110   The DCI timer will start when the optical sensor is activated by the top edge of the piston reaching the 500 cc mark on the steel scale.

111   Continue to flow the gas until the piston reaches the upper optical sensor (2000-cc mark). The DCI timer will automatically stop when the top edge of the piston reaches this point, thus indicating the elapsed time to flow 1500 cc.

112   Push the Brooks Vol-U-Meter Control Box button marked "off."

On Form 310-01, under the column marked Δt seconds (XX.XXX), record the elapsed time obtained from the timer readout.

Note: The Δt must be recorded before the Brooks Vol-U-Meter piston reaches the lower optical sensor. If the time has not been recorded prior to the piston reaching this point, repeat Steps 103 through 112.

113   Repeat Steps 103 through 112 for each of the eight verification target pressures listed on Form 310-01 and record the required data. Each target pressure must be set in the order shown on Form 310-01.

114   When all of the required data points have been collected, complete Form 310-01, Section C.

Note: See the Data Processing Flow Chart on page 9.

9.   Data Input

9.1   The technician opens the CFO Verification Program (on the C&M Macintosh computer) and enters the data recorded on Form 310-01.

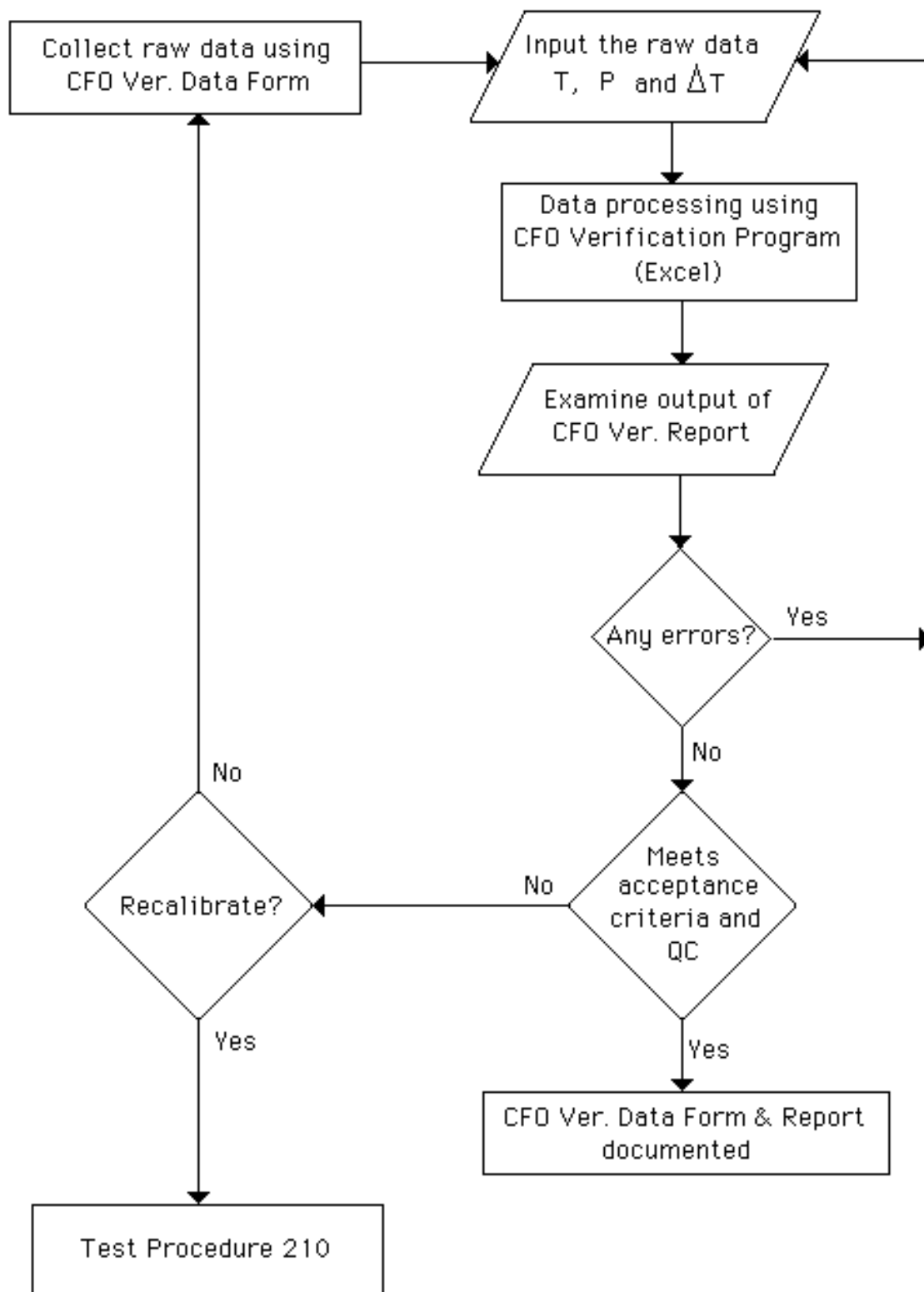9.2   The technician retrieves the active CFO coefficients by pressing the "Get Coefficients" button.

9.3   When all data has been entered, use the scroll bar and move the screen view to the right and preview the "CFO Verification Report."

9.4   The technician verifies that the "CFO Verification Report" does not contain any acceptance criteria flags. If flags appear, see Section 12 for corrective action.

Data Processing Flow Chart

```
Collect raw data using              Input the raw data
   CFO Ver. Data Form      ───────►     T,  P  and ΔT ◄──────────┐
                                             │                    │
                                             ▼                    │
                                    Data processing using         │
                                    CFO Verification Program      │
                                           (Excel)                │
                                             │                    │
                                             ▼                    │
                                     Examine output of            │
                                      CFO Ver. Report             │
                                             │                    │
                                             ▼                    │
                                                     Yes          │
                                      Any errors? ────────────────┘
                                             │
                                            No
                                             │
                                             ▼
      No                              Meets
                              No    acceptance
       │    Recalibrate? ◄────────  criteria and
       │                               QC
       │         │                     │
       │        Yes                   Yes
       │         │                     │
       │         ▼                     ▼
       │                       CFO Ver. Data Form & Report
       │                             documented
       │    Test Procedure 210
       └────────►
```

Test Procedure 210

9.5 The technician saves the file by pressing the "Save Report" button. This will automatically save the data to the hard drive and assign the file name as "CFO Ver Kit # NNNNN MM/DD/YY."

The NNNNN will contain the kit number and the MM/DD/YY will have the date that the data were entered into the computer.

9.6 The technician then prints the "CFO Verification Report" by clicking on the "Print Report" button.

9.7 A technician, other than the one performing the CFO verification, verifies that the data in the "CFO Verification Report" and Form 310-01 are the same.

If no corrections are needed, the technician signs and dates the "CFO Verification Report."

If corrections are needed, they are identified on the report and it is returned to the technician who performed the CFO verification for corrective action.

The technician makes the corrections and repeats Steps 9.1 through 9.6.

10. Data Analysis

10.1 The "CFO Verification Report" is examined for acceptance criteria flags. If flags appear, see Section 12 for corrective action.

10.2 The data in the "CFO Verification Report" and Form 310-01 are compared independently by two technicians.

11. Data Output

11.1 The "CFO Verification Report" and Form 310-01 are filed in the C&M CFO folder.

11.2 The technician notifies the C&M midnight shift that the calibration of the CFO kit has been verified.

12. Acceptance Criteria

The data must meet the following seven criteria to be valid; a flag will be displayed on the "CFO Verification Report" if the data do not meet the criteria.

12.1   The net weight of propane in the tank must be greater than 25 lbs. prior to the start of the verification.

If not, Flag #1 appears on the spreadsheet and the verification is void. Replace the propane cylinder, return to Section 7, complete a new Form 310-01, and repeat the verification procedure.

12.2   The difference between the start and end back-pressure readings must be 0.0 inches H_2O (a reading other than zero indicates friction in the Vol-U-Meter tube).

If it is not zero, Flag #2 appears on the spreadsheet and the verification is void. Notify the C&M Manager, return to Section 7, complete a new Form 310-01, and repeat the verification procedure.

12.3   The difference between the start and end barometric pressure readings must be less than or equal to 0.12 inches Hg.

If not, Flag #3 appears on the spreadsheet and the verification is void. Return to Section 7, complete a new Form 310-01, and repeat the verification procedure.

If after a second verification attempt the data are not within this limit, notify the C&M Manager.

12.4   The difference between the start and end CFO kit thermometer temperature readings must be less than or equal to 2.0 °F.

If not, Flag #4 appears on the spreadsheet and the verification is void. Allow the kit temperature to stabilize for a minimum of two hours, return to Section 7, complete a new Form 310-01, and repeat the verification procedure.

If after a second verification attempt the data are not within this limit, notify the C&M Manager.

12.5 The percent of point deviation from the best fit curve must be within ±0.3% .

If not, Flag #5 appears on the spreadsheet and the out-of-tolerance data points (actual psig and Δt seconds) may be rerun one more time. Cross out the bad data with a single line and initial the area. Open the CFO Verification Program and make the necessary changes.

If the flag persists, the verification is void.

12.5.1 Clean the CFO kit ruby orifice fitting in a sonic bath.

12.5.2 Return to Section 7, complete a new Form 310-01, and complete the verification procedure.

12.5.3 If after a second complete verification attempt the data are not within the specified tolerance, replace the ruby. Return to Section 7, complete a new Form 310-01, and complete the verification procedure.

12.6 The previous calibration date entered into the computer must match the previous calibration date stored in the data base.

If not, Flag #6 appears on the spreadsheet indicating that the coefficients are inactive. Look up the previous calibration date in the CFO folder and verify that the correct date has been recorded on Form 310-01.

If the calibration date is recorded correctly, a computer problem may exist or a report may be missing in the CFO folder; notify the C&M Manager.

12.7 The verification shift must be within ±1.0%. If not, Flag #7 appears.

12.7.1 Clean the CFO kit ruby orifice fitting in a sonic bath.

12.7.2 Return to Section 7, complete a new Form 310-01, and complete the verification procedure.

12.7.3 If after a second complete verification attempt the verification shift is not within this range, replace the ruby and see TP 210 to complete a CFO calibration.

13. Quality Control Provisions

13.1 The fittings are inspected with a leak detection fluid.

13.2 The CFO kit precision pressure gauge is verified to read zero when the shutoff valve is closed.

13.3 The Brooks Vol-U-Meter back-pressure manometer is verified to be reading zero (for the left side of the u-tube) when the Control Box is in the "off" position and the piston is at rest on the bottom.

13.4 If the DCI timer and the Brooks Vol-U-Meter Control Box are not plugged in, they are allowed to warm up for a minimum of two hours.

13.5 The piston movement and back-pressure manometer reading are verified to ensure that there are no fluctuations.

13.6 The flow rate is allowed to stabilize for a minimum of two minutes after each adjustment.

13.7 The net weight of the propane in the tank must be greater than 25 lbs.

13.8 The CFO kit temperature is allowed to stabilize for 20 minutes prior to performing the verification.

13.9 When the piston is moving, the back-pressure manometer must read 1.5 inches of water.

13.10 Actual pressure must be within $\pm\, 0.4$ psig of the target pressure.
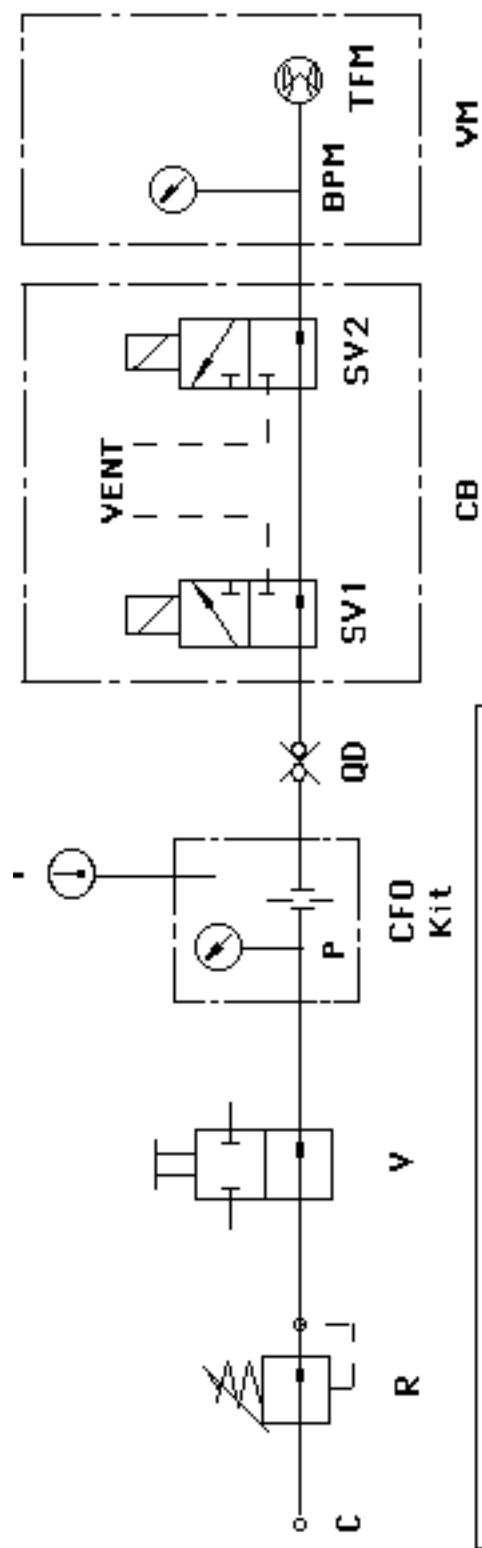
LEGEND

C -------- Cylinder, propane
R -------- Regulator, non-relief type
V -------- Valve, shutoff
CFO ------ Critical Flow Orifice kit
P -------- Pressure gauge, precision
T -------- Thermometer, kit
QD ------- Quick Disconnect
CB ------- Control Box, Brooks Vol-U-Meter
SV1,2 ---- Solenoid Valve, three-way
VM ------- Vol-U-Meter, Brooks
BPM ------ Back-Pressure Manometer
TFM ------ Totalizing Flow Meter
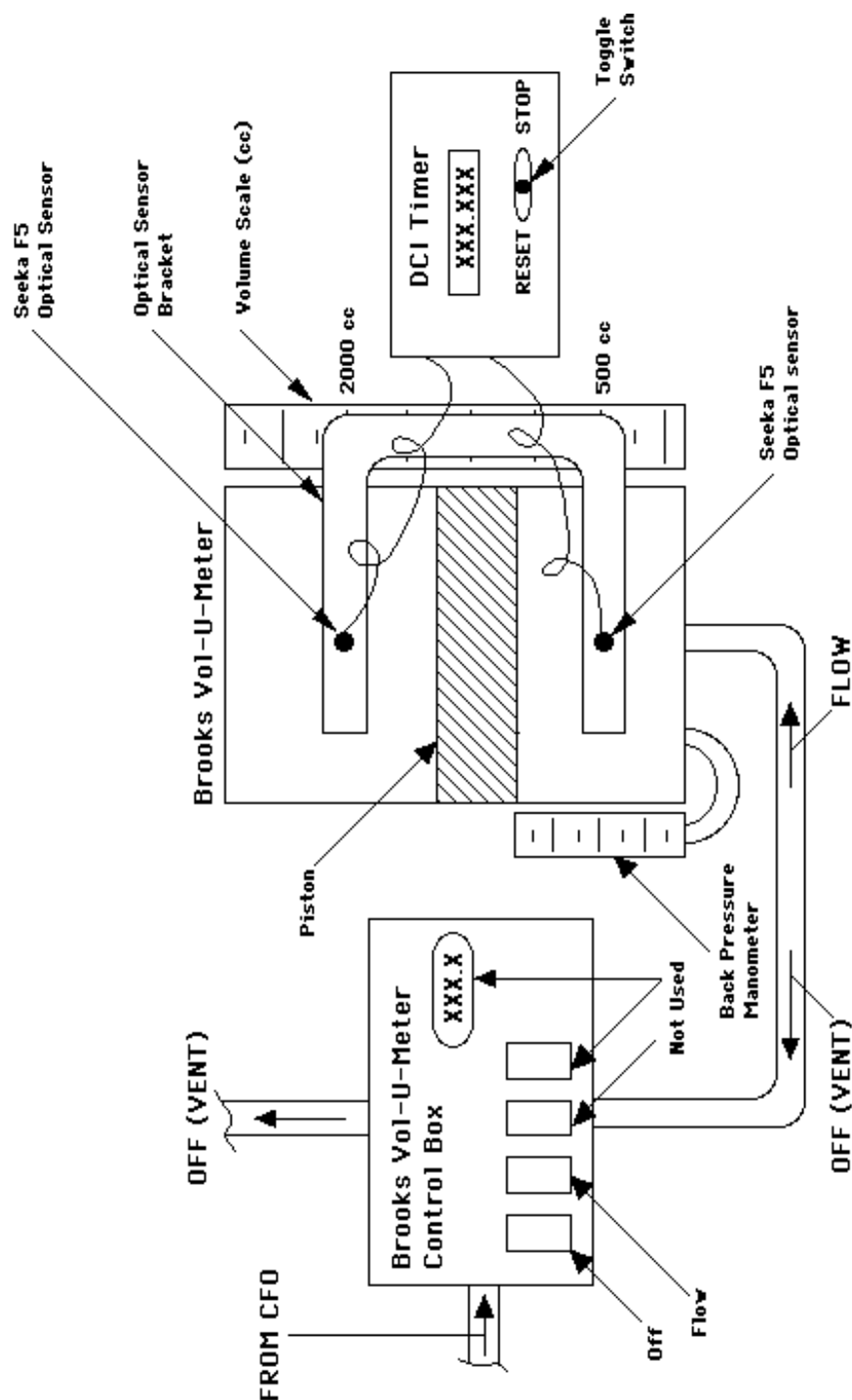   (Tube/Piston)

Figure 1   CFO Verification Schematic

Figure 2   Brooks Vol-U-Meter, Control Box and DCI Timer

CFO Kit/Cart Information

The propane weight is determined by subtracting the CFO kit/cart tare weight, displayed on each kit/cart combination, from the CFO kit/cart total weight. The propane weight must be greater than 25 lbs. for a valid verification.

The following items contribute to the CFO kit/cart total weight:

1. CFO kit

2. Propane cylinder with valve, regulator, and propane gas

3. Portable cart

The following items contribute to the CFO kit/cart tare weight:

1. CFO kit

2. Empty propane cylinder with valve and regulator

3. Portable cart

Listed below are the tare weights of the CFO kits currently in use. Note that the CFO tare weights differ from kit to kit.

Kit Number	Empty Propane Cylinder (lb)	CFO Kit/Cart (lb)	Tare Weight (lb)
038625	95	183	278
086942	95	180	275
181102	95	150	245
181103	95	150	245
106380	95	182	277

CFO Verification Data

Section A:

Technician's Name:_____   Cylinder #:_____

CFO Kit Number: _____   Cylinder Vendor:_____

Current Date: _____   Cylinder Purity:_____

Date of Previous Calibration: _____   CFO Total Weight:_____ lb

Verification Start Time:_____   Start Back Pressure:_____ inches H_2O

Start CFO Kit Thermometer Temp:_____ °F   Start Barometer:_____ inches Hg

Active Coefficients:

A: _____

B: _____

C: _____

Section B: Collect eight verification points in the order listed below.

Target psig	Actual psig, (XX.X)	Δt, seconds (XX.XXX)
(1) **60**	(1) _____	(1) _____
(2) **75**	(2) _____	(2) _____
(3) **85**	(3) _____	(3) _____
(4) **70**	(4) _____	(4) _____
(5) **90**	(5) _____	(5) _____
(6) **95**	(6) _____	(6) _____
(7) **80**	(7) _____	(7) _____
(8) **65**	(8) _____	(8) _____

Section C:

Verification End Time: _____   End Back Pressure: _____ inches H_2O

End CFO Kit Thermometer Temp: _____ °F End Barometer: _____ inches Hg

Ruby Cleaned _____ YES _____ NO

Comments: _____

CFO Kit No: 106360

CFO Verification Report

Processed: Jan-30-1992 13:21

CFO Kit Number	Technician Name	Cylinder Number	Cylinder Purity	Cylinder Vendor	CFO Total Wght (lbs)	Date of Previous Calibration	Current Date
106360	Parker	RC5864	99.50%	Liquid Carbonic	300	11/8/01	11/8/01

	Back Pressure ("H2O)	Barom. Pressure (~Hg)	Kit Temp °F	Cal. Time
START	1.5	2026	75.5	1228
END	1.6	2020	74.5	1431
AVG.	1.6	2023	75.0	
Range	-0.1	0.06	1.0	
FLAGS	#2			

Delta Vol (cc)	CFO Tare Weight (lbs)	Coefficients	Flag #5
1500	277	A =	2.56113E-06
		B =	7.44287E-03
	Propane Weight (lbs)	C =	-1.33518E-02
	23	RUBY YES/NO	
FLAG #1		CLEANED	No

#	Actual PSIG	Delta t (SECS)	$P_s*\sqrt{T_{abs}}$	$A*P^2_{abs}+B*P_{abs}+C$	% Diff	FLAGS
1	60.0	133.628	0.532011	0.554234	-4.01%	#5
2	75.0	108.059	0.652461	0.672167	-2.93%	#5
3	85.0	97.706	0.726937	0.751420	-3.25%	#5
4	70.0	116.864	0.608171	0.632728	-3.88%	#5
5	90.0	92.847	0.765685	0.831203	-3.23%	#5
6	95.0	88.367	0.804321	0.711734	-3.02%	#5
7	80.0	102.963	0.690256	0.791252	-3.02%	#5
8	65.0	124.146	0.572644	0.593417	-3.50%	#5

#	Actual PSIG	Delta t (SECS)	$P_s*\sqrt{T_{abs}}$	$A*P^2_{abs}+B*P_{abs}+C$	% Diff	FLAGS
1	60	133.628	0.532011	0.554234	-4.01%	#5
8	65	124.146	0.572644	0.593417	-3.50%	#5
4	70	116.864	0.608171	0.632728	-3.88%	#5
2	75	108.059	0.652461	0.672167	-2.93%	#5
7	80	102.963	0.690256	0.711734	-3.02%	#5
3	85	97.706	0.726937	0.751420	-3.25%	#5
5	90	92.847	0.765685	0.791252	-3.23%	#5
6	95	88.367	0.804321	0.831203	-3.23%	#5

COMMENTS: QC Limit Flags are present.
This CFO Kit has problems. Replace the rubry and do procedure 210.

DATA VERIFIED BY: _____ DATE: _____